# Nitrogen Oxides Emissions For Alberta 1978-1982

Alberta

85-5344/

# NITROGEN OXIDES EMISSIONS

# FOR ALBERTA

# 1978 - 1982

prepared by:

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## EXECUTIVE SUMMARY

This report provides an inventory of nitrogen oxides emissions for Alberta from major industrial, transportation and combustion sources for the period 1978 to 1982. The nitrogen oxides emissions inventory is provided for source categories which include major industries, transportation, electric utilities, natural gas and heating fuel combustion, and forest fires. Emission estimates of natural gas processing, fertilizer plants, oil sands, petroleum refineries, cement manufacturing, chemical plants, and pulp and paper mills comprise the overall inventory of the major industrial source category. The natural gas processing industry category includes sweet and sour processing plants, reprocessing plants, field facilities, gathering systems, gas injection facilities, and transportation and distribution systems.

On the basis of the source categories outlined in the report, industry and transportation, which contributed about 42.1% and 35.2% respectively of the total nitrogen oxides emissions in 1982, were the major sources. The major industrial source was natural gas processing, which contributed about 33% of the total for 1982.

# NITROGEN OXIDES EMISSIONS FOR ALBERTA

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# I INTRODUCTION

The Air Quality Control Branch of the Pollution Control Division of Alberta Environment carried out the task of updating the "Nitrogen Oxides Emissions for Alberta" publication compiled in December, 1980 by the Research Management Division of Alberta Environment.

Nitrogen oxides emissions inventories are an important part of any pollution control program. The information summarized in this report is useful for determining control strategies, developing regulations, locating air monitoring networks and determining the effectiveness of control programs. A high priority has been given to the control of industrial acid rain-causing pollutants in Alberta. To monitor the progress and future trends of the nitrogen oxides emissions, it is necessary to update the emission inventory on a regular basis.

This report provides the nitrogen oxides source and emissions inventory for Alberta for the period 1978 to 1982. Nitrogen oxides emissions are a major class of air pollutants released to the atmosphere by many industrial and transportation sources. The industrial emission data compiled in this report were obtained from manual stack survey results whenever possible. The natural gas processing industry emissions, however, are estimates based on fuel consumption data. Emission estimates for most of the other categories were made using annual fuel consumption and production statistics. These were multiplied by applicable emission factors provided by the U.S. Environmental Protection Agency or Environment Canada to give overall totals for the year. Deviations from this procedure are noted in the tables.

Nitrogen oxides emissions are expressed in terms of nitrogen dioxide ($NO_2$) throughout this report.

## II. SUMMARY

A summary of the nitrogen oxides emissions by source category in Alberta covering the period 1978 to 1982 is provided in Table 1. The source categories consist of major industries, transportation, electric utilities, natural gas and heating fuel combustion, and forest fires. The percentage of nitrogen oxides emissions from the various source categories from 1978 through 1982 are listed in Table 2. Figure 1 shows that the industrial and transportation sectors, which contributed about 77% of the total emissions in 1982, were the major sources of nitrogen oxides emissions. The trend of nitrogen oxides emissions from each of the source categories is illustrated in Figure 2.

Table 3 presents a summary of the nitrogen oxides emissions of the major industrial sources. Emission estimates of natural gas processing, fertilizer plants, oil sands plants, cement manufacturing, chemical plants, petroleum refineries, and pulp and paper mills represent the industrial sources. Natural gas processing is the major contributor. Figure 3 provides a trend of the relative contributions of the various industries in Alberta for the period 1978 to 1982.

TABLE 1

SUMMARY OF NITROGEN OXIDES
EMISSIONS BY SOURCE CATEGORY
(TONNES/YEAR)

| Source | 1978 | 1979 | 1980 | 1981 | 1982 |
|---|---|---|---|---|---|
| 1. Major Industrial Sources | 134,650 | 137,787 | 141,564 | 143,377 | 148,735 |
| 2. Transportation | 112,732 | 121,626 | 129,586 | 130,730 | 124,572 |
| 3. Electric Utilities | 35,584 | 39,876 | 48,925 | 49,180 | 46,517 |
| 4. Natural Gas and Heating Fuel Combustion | 16,806 | 18,985 | 24,424 | 22,389 | 21,984 |
| 5. Forest Fires | 67 | 5,467 | 18,841 | 38,985 | 11,703 |
| TOTAL | 299,839 | 323,741 | 363,340 | 384,661 | 353,511 |

Note:

- The industrial source category includes emission estimates for the natural gas processing, fertilizer plants, oil sands plants, cement manufacturing, chemical plants, petroleum refineries and pulp and paper mills.
- The transportation source category includes emission estimates for passenger cars, commercial vehicles and railways.
- The electric utilities category includes emission estimates from all power plants in Alberta.
- The natural gas and heating fuel combustion category includes emission estimates from the residential, commercial and industrial sectors.
- The forest fire category is based on emission estimates for forested areas consumed by fire on productive and potentially productive land. Non-productive land consumed by forest fires is not considered in the estimates.

TABLE 2

PERCENTAGE OF NITROGEN OXIDES
EMISSIONS BY SOURCE CATEGORY FOR THE PERIOD 1978-1982

| Source | 1978 | 1979 | 1980 | 1981 | 1982 |
|---|---|---|---|---|---|
| 1. Major Industrial Sources | 44.9 | 42.6 | 38.9 | 37.3 | 42.1 |
| 2. Transportation | 37.6 | 37.6 | 35.7 | 34.0 | 35.2 |
| 3. Electric Utilities | 11.9 | 12.3 | 13.5 | 12.8 | 13.2 |
| 4. Natural Gas and Heating Fuel Combustion | 5.6 | 5.8 | 6.7 | 5.8 | 6.2 |
| 5. Forest Fires | 0.0 | 1.7 | 5.2 | 10.1 | 3.3 |

FIGURE 1. NITROGEN OXIDES EMISSIONS IN ALBERTA (1982)

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# FIGURE 2. TREND OF NITROGEN OXIDES SOURCE AND EMISSION ESTIMATES FOR ALBERTA (1978-1982)

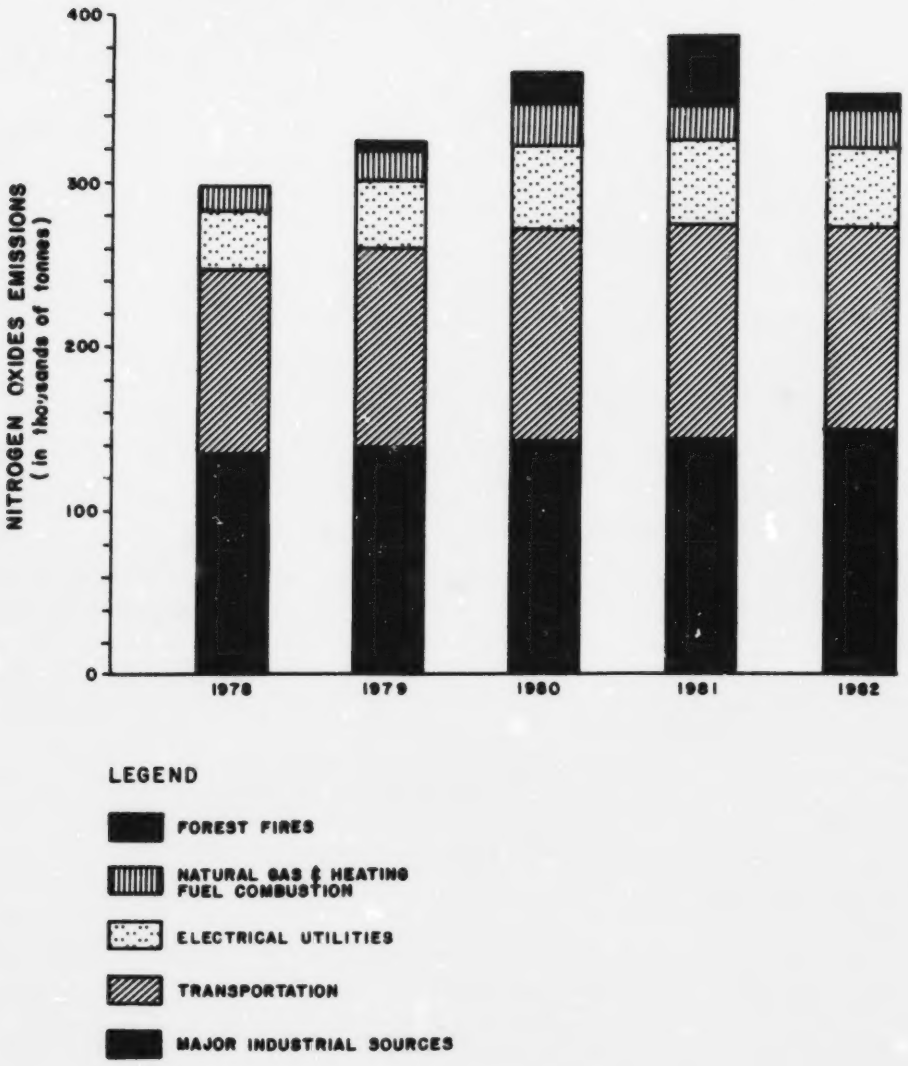


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TABLE 3

TOTAL NITROGEN OXIDES EMISSIONS (TONNES/YEAR)[a,b]
FROM INDUSTRIAL SOURCES IN ALBERTA 1978-1982

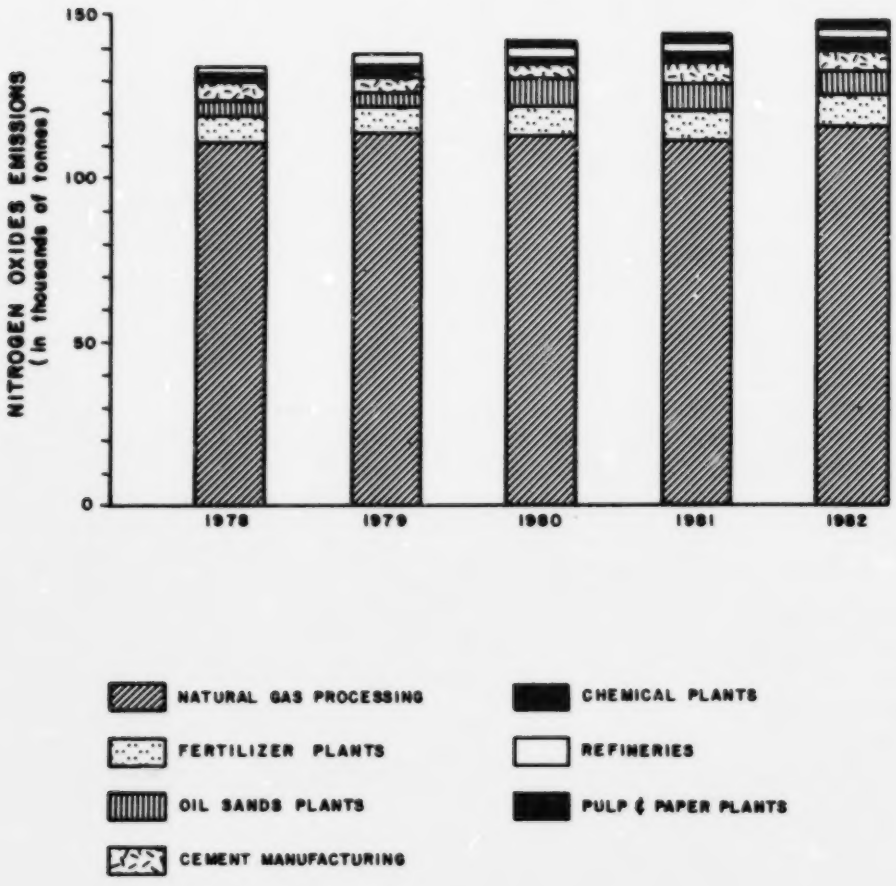
| Industry | 1978 | 1979 | 1980 | 1981 | 1982 |
|---|---|---|---|---|---|
| Cement Manufacturing | 4300 | 4800 | 5070 | 6620 | 6090 |
| Fertilizer Plants | 8248 | 8174 | 8783 | 7976 | 7249 |
| Chemical Plants | 3442 | 4423 | 2458 | 2728 | 4049 |
| Refineries | 1933 | 1949 | 1822 | 2292 | 2278 |
| Natural Gas Processing | 110,727 | 113,441 | 113,021 | 110,951 | 116,509 |
| Oil Sands Plants | 6000 | 5000 | 8700 | 9900 | 9500 |
| Pulp & Paper Mills | N/A | N/A | 1710 | 2910 | 3060 |
| TOTAL | 134,650 | 137,787 | 141,564 | 143,377 | 148,735 |

[a] Estimated as $NO_2$

[b] Note that nitrogen oxides emission estimates from remaining industries are shown in Table 12.

N/A Not Available

# FIGURE 3. TREND OF NITROGEN OXIDES EMISSIONS FROM MAJOR INDUSTRIES IN ALBERTA (1978 - 1982)

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## III NITROGEN OXIDES EMISSIONS FROM MAJOR SOURCES

This section contains the data on nitrogen oxides emissions for the various industrial, transportation, electric utility, combustion and forest fire sources contributing to the emissions inventory in Alberta for the period 1978 to 1982. Tables 3 to 13 provide the breakdown on a year-to-year basis of the nitrogen oxides emissions for these sources.

TABLE 4

NITROGEN OXIDES EMISSIONS (TONNES/YEAR)
FROM NATURAL GAS PROCESSING IN ALBERTA[a,b]

| Source | 1978 | 1979 | 1980 | 1981 | 1982 |
|---|---|---|---|---|---|
| 1. Compressors (reciprocating)[c] | | | | | |
| Processing Plants: | | | | | |
| - sour gas | 24099 | 24581 | 25232 | 24667 | 25673 |
| - sweet gas | 36857 | 37594 | 33495 | 32745 | 34079 |
| Field | 4181 | 4469 | 4371 | 4203 | 4458 |
| Gathering Systems | 29089 | 28910 | 32652 | 32678 | 34562 |
| Transportation & Distribution | 1693[d] | 2011 | 1698 | 1563 | 2003 |
| Gas Injection | 2338[d] | 2404 | 2618 | 2529 | 2543 |
| Subtotal | 98257 | 99969 | 100066 | 98385 | 103318 |
| 2. Compressors (turbine)[c] | | | | | |
| Gathering Systems | 130 | 129 | 146 | 146 | 154 |
| Transportation & Distribution | 1293[d] | 1536 | 1297 | 1193 | 1530 |
| Reprocessing Plants | 1562 | 1957 | 1739 | 1715 | 1592 |
| Gas Injection | 198[d] | 204 | 222 | 215 | 216 |
| Subtotal | 3183 | 3826 | 3404 | 3269 | 3492 |
| 3. Heaters and Boilers[c] | | | | | |
| Processing Plants: | | | | | |
| - sour gas | 5231 | 5336 | 5477 | 5354 | 5572 |
| - sweet gas | 1326 | 1352 | 1205 | 1178 | 1226 |
| Field | 2513 | 2686 | 2627 | 2527 | 2680 |
| Reprocessing Plants | 217 | 272 | 242 | 238 | 221 |
| Subtotal | 9287 | 9646 | 9551 | 9297 | 9699 |
| TOTAL | 110727 | 113441 | 113021 | 110951 | 116509 |

a Estimated as $NO_2$.
b The inventory is based on fuel consumption data obtained from Alberta Gas Plant Statistics - E.R.C.B. Fuel usage fractions (percentage of fuel used for reciprocating engine and turbine type compressor, and heaters and boilers) obtained from Dr. M. Winning (Shell Canada Ltd., 1980) and M. Zelensky (Western Research, 1983).
c Emission factors were obtained from U.S. Environmental Protection Agency 1981.
Compressors (reciprocating) - 55400 $kg/10^6 m^3$
Compressors (turbines) - 4700 $kg/10^6 m^3$
Heaters and boilers - 3700 $kg/10^6 m^3$
d Estimated through extrapolation from 1979-1982 data.

TABLE 5

NITROGEN OXIDES EMISSIONS (TONNES/YEAR) FROM OIL SANDS INDUSTRY IN ALBERTA [a,b]

| Source | 1978 | 1979 | 1980 | 1981 | 1982 |
|---|---|---|---|---|---|
| Suncor | 5500[c] | 4500[c] | 5400[c] | 4500[c] | 4200[c] |
| Syncrude | N/A[d] | N/A[d] | 2800[c] | 4900[c] | 4800[c] |
| In-situ Heavy Oil Pilots[e] | 500 | 500 | 500 | 500 | 500 |
| TOTAL | 6000 | 5000 | 8700 | 9900 | 9500 |

[a] Estimated as $NO_2$.
[b] Other types of oil sands plants produce heavy oil by means other than open pit mining (personal communication, Air Quality Control Branch, Alberta Environment, 1980).
[c] Estimated from stack surveys.
[d] Started operation in Summer 1978. Estimate not available. No manual stack surveys available.
[e] Estimated based upon an emission factor of $1.32 \times 10^{-3} t/m^3$ synthetic crude oil and 50% of licenced production.

TABLE 6

NITROGEN OXIDES EMISSIONS (TONNES/YEAR) FROM FERTILIZER PLANTS IN ALBERTA [a,b,c,e]

| Plant (Location) | 1978 | 1979 | 1980 | 1981 | 1982 |
|---|---|---|---|---|---|
| Esso Chemical Canada (Redwater) | 185 | 248 | 155 | 178 | 113 |
| Cominco (Calgary) | 389 | 374 | 337 | 438 | 391 |
| Cominco (Carseland) | 2897 | 2897 | 2820 | 3594 | 2631 |
| C.I.L. (Carseland) | 129 | 129 | 132 | 68 | 198 |
| Western Co-op Ltd.[d] (Calgary) | 838 | 838 | 1872 | 1026 | 376[f] |
| Western Co-op Ltd. (Medicine Hat) | 686 | 564 | 989 | 756 | 563 |
| Sherritt Gordon Mines Ltd. (Fort Saskatchewan) | 46 | 46 | 46 | 46 | 46 |
| Canadian Fertilizer Ltd. (Medicine Hat) | 3078 | 3078 | 2432 | 1870 | 2931 |
| TOTAL | 8248 | 8174 | 8783 | 7976 | 7249 |

[a] Estimated as $NO_2$.
[b] The emission results reflect emissions mainly due to process production as opposed to utility usage purposes and constitute the best data available. Sources such as boiler stacks are not required to be monitored in all current licence conditions as emission rates from these sources are low in relation to the other sources within the plants (personal communication, L. Begoray, Air Quality Control Branch, Alberta Environment, 1983).
[c] Estimated from stack surveys and 330 operational days unless otherwise noted.
[d] 1980 estimate used for 1978-79 emission based on stack surveys and 330 operational days.
[e] 1980, 1981 estimates based on stack surveys and 300 operational days with the exception of Sherritt Gordon Mines Ltd.
[f] Extended plant shutdown during 1982.

TABLE 7

NITROGEN OXIDES EMISSIONS (TONNES/YEAR) FROM CEMENT MANUFACTURING INDUSTRY IN ALBERTA [a,b]

| Plant (Location) | 1978 | 1979 | 1980 | 1981 | 1982 |
|---|---|---|---|---|---|
| Canada Cement (Exshaw) | 1900 | 2000 | 1700 | 3350 | 4360 |
| Genstar Cement (Edmonton) | 2400 | 2800 | 3370 | 3270 | 1730 |
| TOTAL | 4300 | 4800 | 5070 | 6620 | 6090 |

[a] Estimated as $NO_2$.
[b] Estimates are based on stack surveys and actual operational time during the year based on production data.

TABLE 8

NITROGEN OXIDES EMISSIONS (TONNES/YEAR) FROM REFINERIES IN ALBERTA [a]

| Plant (Location) | 1978 | 1979 | 1980 | 1981 | 1982 |
|---|---|---|---|---|---|
| Esso[b] (Edmonton) | 942 | 982 | 1202 | 1313 | 1143 |
| Gulf[b] (Edmonton) | 531 | 507 | 579 | 812 | 979 |
| Texaco[b] (Edmonton) | 460 | 460 | 41[e] | 167 | 156[e] |
| Shell[d] (Bowden) | - | - | - | - | - |
| Husky Oil[c] (Lloydminster) | - | - | - | - | - |
| TOTAL | 1933 | 1949 | 1822 | 2292 | 2278 |

[a] Estimated as $NO_2$.
[b] Estimated from stack surveys and usual operational time of 365 days.
[c] Largest single $NO_x$ source would be an incinerator--no estimates.
[d] Essentially less than 1 tonne per day of $NO_x$ emissions--no estimate of emissions.
[e] Based on 1 stack survey.

TABLE 9

NITROGEN OXIDES EMISSIONS (TONNES/YEAR) FROM CHEMICAL PLANTS IN ALBERTA [a]

| Plant (Location) | 1978 | 1979 | 1980 | 1981 | 1982 |
|---|---|---|---|---|---|
| Alberta Gas Chemicals (Medicine Hat) | 142 | 23 | 243 | 323 | 722[e,f] |
| Celanese Canada (Edmonton) | 2700[b] | 2700[b] | 515[b] | 705[b] | 415 |
| Dow Chemical (Fort Saskatchewan) | 300[b] | 1100[b] | 1100[b] | 1100[b] | 1798[d] |
| Alberta Gas Ethylene (Joffre) | N/O | 300[b] | 300[b] | 300[b] | 814[e] |
| Subtotal | 3142 | 4123 | 2158 | 2428 | 3749 |
| Other Plants[c] | 300 | 300 | 300 | 300 | 300 |
| TOTAL | 3442 | 4423 | 2458 | 2728 | 4049 |

[a] Estimated as $NO_2$.

[b] Estimates are based on stack surveys, licence requirements and 330 operational days. The values presented in the table are considered to be representative of overall $NO_x$ emissions from the plants. These computations were based on stack surveys conducted at the plants. Some small sources of $NO_x$ at the plants are not required to be surveyed. It is believed that their contributions to the overall $NO_x$ emissions would be insignificant (personal communications, W. Macdonald, Air Quality Control Branch, Alberta Environment, 1983).

[c] Estimated for unsurveyed plants by the Air Quality Control Branch of Alberta Environment.

[d] Based on maximum licence requirements and 330 operational days assuming full capacity.

[e] Estimate based on stack surveys, total production hours and average capacity.

[f] Reformer stack from plant #3 went into operation in 1982.

TABLE 10

NITROGEN OXIDES EMISSIONS (TONNES/YEAR) FROM PULP & PAPER MILLS IN ALBERTA [a]

| Plant (Location) | 1978 | 1979 | 1980 | 1981 | 1982 |
|---|---|---|---|---|---|
| Procter and Gamble (Grande Prairie) | N/A | N/A | 1710[b] | 2610[b] | 2760[b] |
| St. Regis (Hinton) | N/A | N/A | N/A | N/A | 300[c] |
| TOTAL | - | - | 1710 | 2610 | 3060 |

[a] Estimated as $NO_2$.
[b] Estimates are based on stack tests on the recovery boiler, power boiler and lime kiln, and 360 operating days per year.
[c] Estimates are based on stack tests on the main boiler and lime kiln.

N/A Not Available.

TABLE 11

NITROGEN OXIDES EMISSIONS (TONNES/YEAR) FROM POWER PLANTS IN ALBERTA[a]

| Plant/Operator/Location | 1978 | 1979 | 1980 | 1981 | 1982 |
|---|---|---|---|---|---|
| Wabamun-Transalta (Lake Wabanum)[b] | 4804 | 5518 | 6446 | 3901 | 5183 |
| Sundance-Transalta (Lake Wabamun)[b] | 17739 | 20527 | 26757 | 26486 | 27922 |
| Rossdale-Edm. Power (Edm.)[c] | 2221 | 993 | 486 | 439 | 302 |
| Cloverbar-Edm. Power (Edm.)[c] | 1641 | 2333 | 2794 | 1393 | 815 |
| Battle River-Alberta Power (Forestburg)[b,d] | 2082 | 3343 | 4940 | 8953 | 6016 |
| H.R. Milner-Alberta Power (Grande Cache)[b,d] | 1124 | 979 | 885 | 1390 | 1305 |
| Jasper-Alberta Power (Jasper) | 549[e] | 447[e] | 487[e] | 488[e] | 172[b] |
| Medicine Hat-City of M.H. (Medicine Hat) | 996[e] | 1308[e] | 1702[e] | 1702[e] | 374[b] |
| Subtotal | 31156 | 35448 | 44497 | 44752 | 42089 |
| Steam Plants[f] | 328 | 328 | 328 | 328 | 328 |
| Other Plants[g] | 4100 | 4100 | 4100 | 4100 | 4100 |
| TOTAL | 35584 | 39876 | 48925 | 49180 | 46517 |

[a] Estimated as $NO_2$.

[b] Industry capacity figures (based on time utilized and amount of operation time) and stack survey results are the bases of estimates.

[c] Edmonton Power provided detailed gross power output figures which allowed calculation of a capacity figure for yearly operations. Capacity figures and stack surveys were utilized for emission estimates.

[d] Industry operational time per year and percentage output factors were coupled with stack surveys for emission estimates.

[e] Estimates based on stack surveys and 300 operational days, assuming 100% capacity 24 hours per day.

[f] Only one stack survey available, operating approximately at 50% capacity; assumed linear relation to other steam plants.

[g] An estimate for smaller plants that run on diesel and natural gas. Estimate based on total megawatts produced and an emission factor from Environment Canada (1978).

TABLE 12

NITROGEN OXIDES EMISSIONS (TONNES/YEAR) FROM TRANSPORTATION SOURCES IN ALBERTA[a]

| Source | 1978 | 1979 | 1980 | 1981 | 1982 |
|---|---|---|---|---|---|
| Commercial Vehicles[c] | | | | | |
| Light Duty | 7425 | 8060 | 8413 | 8295 | 7416 |
| Medium Duty | 3703 | 4020 | 4196 | 3825 | 3553 |
| Heavy Duty (gasoline) | 3697 | 4013 | 4189 | 4190 | 4032 |
| Heavy Duty (diesel) | 54207 | 58841 | 61418 | 62692 | 61473 |
| Subtotal | 69032 | 74934 | 78216 | 79002 | 76474 |
| Passenger Cars[b] | 31819 | 34390 | 37650 | 38056 | 36007 |
| Railways[d] | 11881 | 12302 | 13720 | 13672 | 12091 |
| TOTAL | 112732 | 121626 | 129586 | 130730 | 124572 |

[a] Estimated as $NO_2$.

[b] Based on number of registered vehicles (Alberta Solicitor General, 1983); an average travelling distance of 18,520 km and composite emission factors of 1.81 g/km for 1978-1980; 1.73 g/km for 1981; and 1.57 g/km for 1982 (Research Management Division, 1983; Alberta Oxides of Nitrogen Emissions Forecast 1980 to 2000).

[c] Based on the following factors:

| | light duty | medium duty | heavy duty (gasoline) | heavy duty (diesel) |
|---|---|---|---|---|
| % of total commercial vehicles | 63.2 | 18.9 | 6.7 | 11.2 |
| average driving distance (km) | 15770 | 19780 | 21800 | 80520 |
| composite emission factors (g/km) | | | | |
| 1978-1980 | 1.76 | 2.34 | 5.98 | 14.2 |
| 1981 | 1.70 | 2.09 | 5.86 | 14.2 |
| 1982 | 1.55 | 1.98 | 5.76 | 14.2 |

Sources: as per footnote b

[d] Based on fuel oil consumption data (Alberta Treasury 1980, 1983) and an emission factor from Environment Canada (1978) of 44 kg/1000 litres.

TABLE 13

NITROGEN OXIDES EMISSIONS (TONNES/YEAR) FROM
NATURAL GAS AND HEATING FUEL COMBUSTION SOURCES IN ALBERTA[a]

| Source | 1978 | 1979 | 1980 | 1981 | 1982 |
|---|---|---|---|---|---|
| Residential | 3121[b] | 4121[b] | 3723[c] | 3870[c] | 4187[c] |
| Commercial | 4083[b] | 4292[b] | 4641[d] | 4284[d] | 3927[d] |
| Industrial | 9602[b] | 10572[b] | 16060[e] | 14235[e] | 13870[e] |
| TOTAL | 16806 | 18985 | 24424 | 22389 | 21984 |

[a] Estimated as $NO_2$.

[b] Based on data provided in "Nitrogen Oxides Emissions for Alberta 1976 to 1979". Prepared for Alberta Environment, Research Management Division, RMD Report 80/3.

[c] Based on "Alberta Oxides of Nitrogen Emissions Forecast 1980 to 2000", Research Management Division, RMD Report 83/26 in which natural gas requirements were obtained from Alberta Electrical Utility Planning Council. The emission factors in these estimates were obtained from EPA (1981) and are as follows:

34 ng/J - gas fired
32 ng/J - propane fired
58 ng/J - oil fired

[d] Based on "Alberta Oxides of Nitrogen Emission Forecast 1980 to 2000", Research Management Division, RMD Report 83/26. The emission factor used in these estimates, obtained from EPA (1981), is as follows: 51 ng/J - gas fired.

[e] Based on "Alberta Oxides of Nitrogen Emission Forecast 1980 to 2000", Research Management Division, RMD Report 83/26 in which industrial gas requirements were obtained from ERCB, coupled with an emission factor of 257 ng $NO_2$/J of natural gas input, EPA (1981).

TABLE 14

TOTAL NITROGEN OXIDES EMISSIONS (TONNES/YEAR) FROM FOREST FIRES IN ALBERTA [a,b,c,d]

| Source | 1978 | 1979 | 1980 | 1981 | 1982 |
|---|---|---|---|---|---|
| Forest Fires | 70 | 5470 | 18840 | 38990 | 11700 |
| TOTAL | 70 | 5470 | 18840 | 38990 | 11700 |

[a] Areas consumed by fire of greater than 12 hectares were included in these estimates.

[b] Forest fire statistics were obtained from the Alberta Forest Service Division of Alberta Energy and Natural Resources.

[c] Nitrogen oxides emissions were estimated based on 100% of the area consumed by fire on productive land and 50% of the area consumed by fire on potentially productive land. Non-productive land consumed by forest fire was not considered in estimating nitrogen oxides emissions.

[d] Emission factors utilized were as follows:
44.8 kg of $NO_x$/hectare consumed for conifers
53.8 kg $NO_x$/hectare consumed for hardwood
(Saskatchewan Environment 1982).

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